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(54) **AUTOMATIC BALANCING ROTOR FOR CENTRIFUGE**

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See application file for complete search history.

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(57) **ABSTRACT**

An automatic balancing rotor for a centrifuge which compensates for imbalance of a centrifugal force occurring due to a weight difference of samples. The automatic balancing rotor includes a plurality of rotating arms spaced at regular angular intervals, with a plurality of buckets containing the samples supported by the rotating arms. The automatic balancing rotor includes a balance weight provided in each of the rotating arms to be movable in a radial direction, thus compensating for imbalanced centrifugal force applied to the buckets, and a balance weight mover which horizontally moves the balance weight in the radial direction of each of the rotating arms.

5 Claims, 3 Drawing Sheets
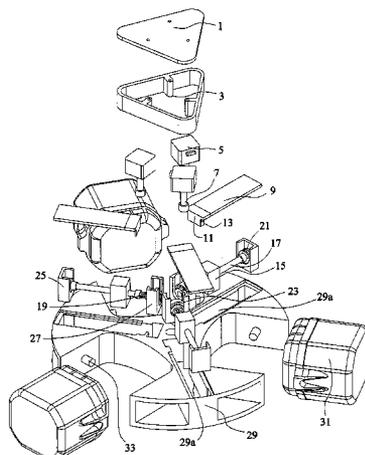
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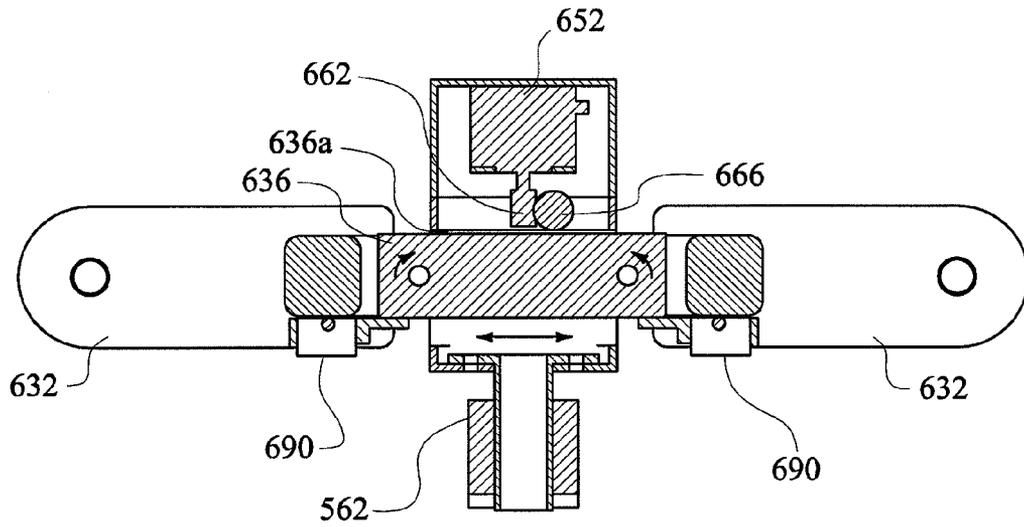English language Abstract of JP 06-247331, published Sep. 6, 1994.
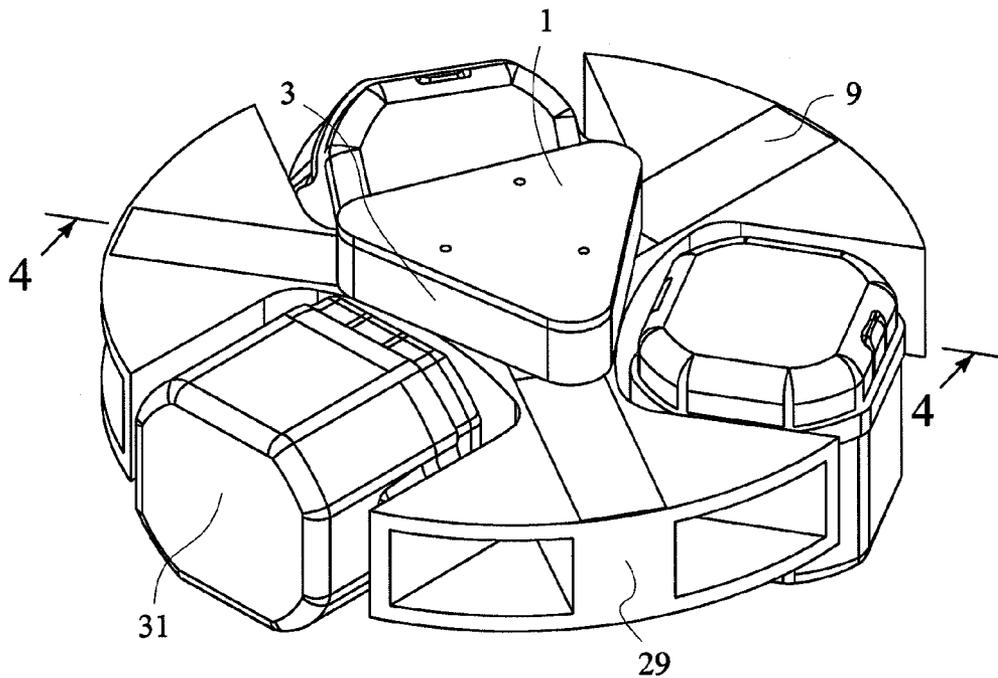
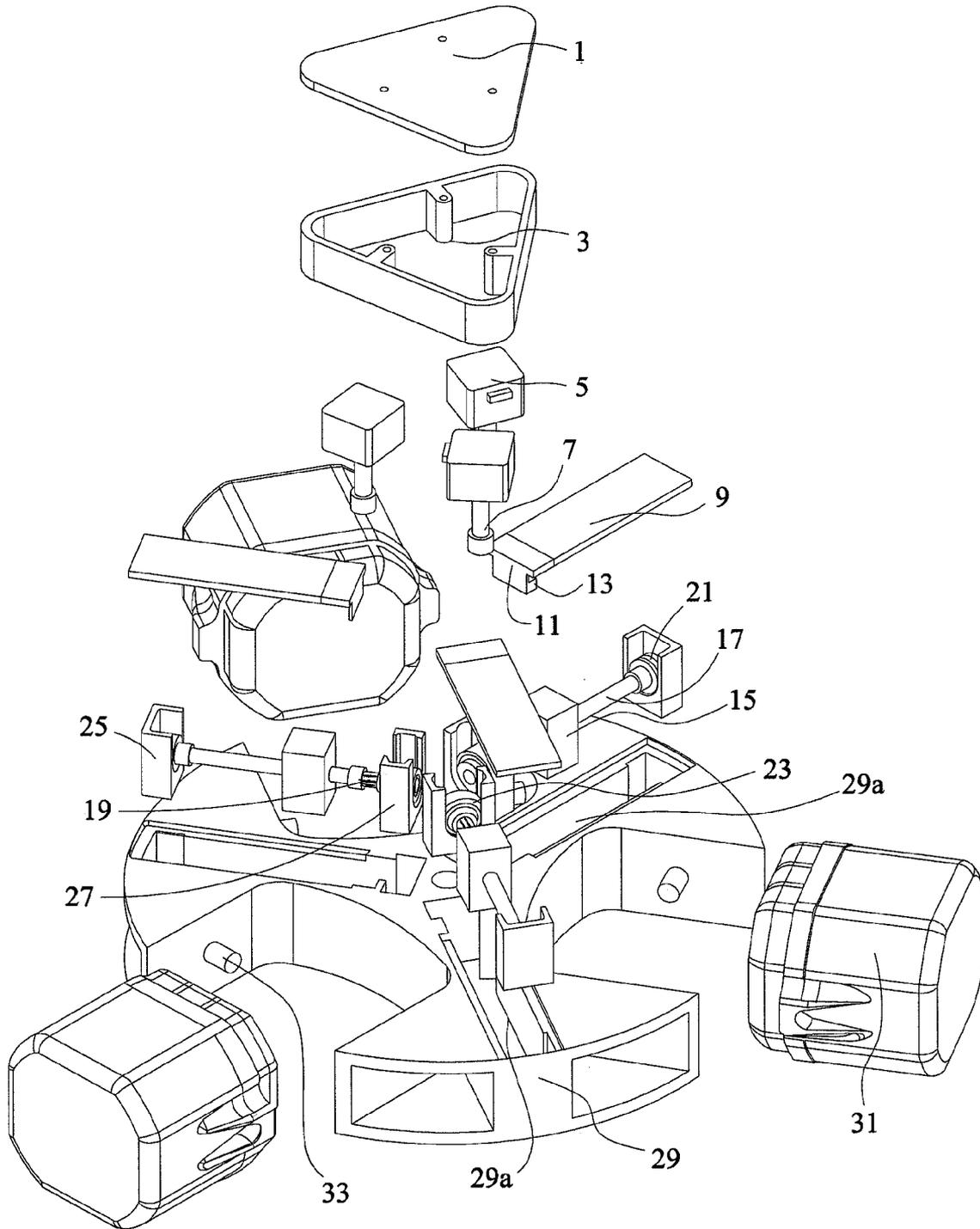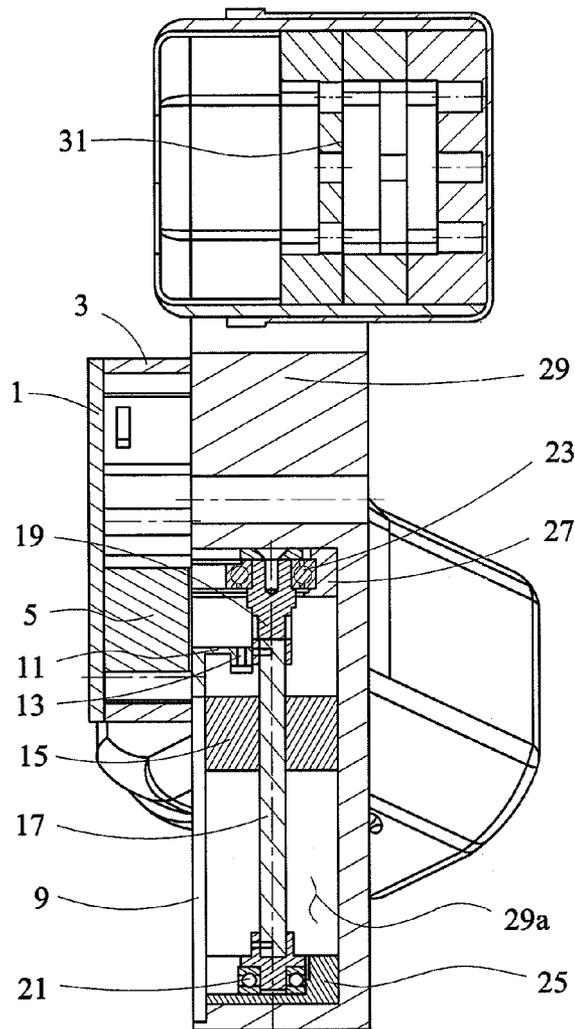* cited by examiner
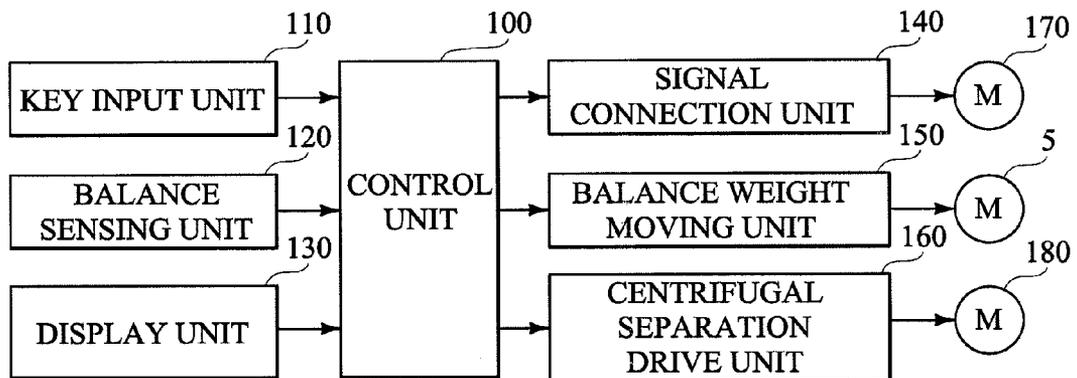
FIG. 1
Prior Art

FIG. 2

FIG. 3

FIG. 4

FIG. 5

AUTOMATIC BALANCING ROTOR FOR CENTRIFUGE

TECHNICAL FIELD

The present invention relates, in general, to automatic balancing rotors for centrifuges and, more particularly, to an automatic balancing rotor for centrifuges which senses imbalance of the weight of samples, contained in buckets, prior to every centrifugal separation and radially moves balance weights, provided in rotor aims, according to the weight sensing result, thus dynamically maintaining balance during the centrifugal separation.

BACKGROUND ART

Generally, centrifuges are apparatuses m which a rotor containing samples is rotated at high speed to apply a high centrifugal force to the samples, so that a high density fraction is moved radially outwards and a low density fraction is moved radially inwards, thus separating the fractions from each other.

FIG. 1 is a sectional view showing a conventional automatic balancing rotor for centrifuges. As shown in FIG. 1, the conventional automatic balancing rotor for centrifuges uses a mechanism, in which a lever central body 636 is horizontally moved according to a control algorithm, to compensate for imbalance between samples contained in buckets supported by rotational aims 632. Here, the lever moving mechanism includes a worm 662 which is axially coupled to a lever moving motor 652, a worm gear (not shown) which engages with the worm 662, a pinion 666 which is coaxially coupled to the worm gear, and the lever central body 636 having a rack 636a, which engages with the pinion 666.

Furthermore, a pressure sensor 690 is provided under each rotational arm 632 to measure the weight of the sample contained in the associated bucket (not shown). A wiring layer 562 is integrally coupled to a lower part of the rotor to receive an electrical signal from the pressure sensors 690 and transmit an electrical signal to the lever moving motor 652 according to a control algorithm, thus balancing the centrifuge.

The conventional automatic balancing rotor for centrifuges having the above-mentioned construction senses imbalance of the samples by measuring the weight of the buckets provided at both ends of the rotor lever, and controls the distance between each bucket and a rotating shaft of the rotor according to the weight difference of the samples, thus applying the same centrifugal force to the opposite buckets containing the samples. Thereby, the samples contained in the buckets maintain a dynamic balance state during the rotation of the rotor for centrifugal separation. More details are described in Korean Application No. 10-2002-0017498 (publication date: Apr. 17, 2002) which was filed by the inventor of the present invention, therefore further explanation is deemed unnecessary.

DISCLOSURE OF INVENTION

Technical Problem

However, in the above-mentioned conventional automatic balancing rotor for centrifuges, because the rotor is balanced by moving the lever central body in a radial direction of the rotor, as the weight difference between the opposite buckets

containing samples increases, a rotational radius of the rotor lever increases. Therefore, the space required for rotation of the rotor increases.

Moreover, as the distance from the rotating center to one bucket containing a sample increases, the distance from the rotating center to the other bucket is reduced by the increased distance of the opposite side. Then, centrifugal force is differentially applied to the samples contained in the opposite buckets. Thereby, the samples may be excessively or incompletely separated. Furthermore, there is a predetermined minimum limit in balancing the rotor due to a limited distance that the lever central body is horizontally moved, and due to back lash of a horizontal moving unit

Technical Solution

Accordingly, the present invention has been made keeping in mind the above problems occurring in the prior art, and an object of the present invention is to provide an automatic balancing rotor for centrifuges which compensates for an imbalance of a centrifugal force due to a weight difference of samples by horizontally moving balance weights provided in rotor arms without changing the length of the rotor aims, thus reducing the space that the automatic balancing rotor occupies, and applying the same centrifugal force to the samples contained in the buckets, and preventing the rotor from being affected by back lash during the automatic balancing process.

Advantageous Effects

In an automatic balancing rotor for centrifuges according to the present invention, imbalance of a centrifugal force of the rotor due to a weight difference of samples is compensated for by controlling rotational radii of balance weights provided in rotor arms. Therefore, vibration of the automatic balancing rotor due to imbalance is prevented from occurring during centrifugal separation, thereby the lifetime of the automatic balancing rotor and of a centrifuge having the rotor is extended, and the samples are prevented from damage.

Furthermore, because it is unnecessary for a user to weigh the samples or control the number of samples, the centrifugal separation of the samples is correctly and rapidly executed, thus reducing the time required for the centrifugal separation. In addition, compared with conventional two-arm swing rotors using a method of directly moving a rotor lever, the automatic balancing three-arm rotor of the present invention using a balance weight moving method can reduce the space required for centrifugal separation, therefore it is particularly useful in a centrifuge having a large capacity. As well, because the slot to guide the balance weight can be longitudinally formed through nearly all of the rotor arm, a sufficient balance weight moving distance is ensured, thereby minimizing the effect of back lash occurring between the balance weight and the balance weight moving shaft.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view showing a conventional automatic balancing rotor for centrifuges;

FIG. 2 is a perspective view of an automatic balancing rotor for centrifuges, according to an embodiment of the present invention;

FIG. 3 is an exploded perspective view of the automatic balancing rotor of FIG. 2;

FIG. 4 is a sectional view of the automatic balancing rotor taken along the line 4-4 of FIG. 2; and

FIG. **5** is an electrical block diagram of a centrifuge having the automatic balancing rotor of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

In order to accomplish the above object(s), the present invention provides an automatic balancing rotor for a centrifuge, including: a plurality of rotating arms having the same radial length and being arranged around a centrifugal rotating shaft, and being spaced out at regular angular intervals, with a plurality of buckets containing samples therein supported by the rotating arms; a balance weight provided in each of the rotating arms to be movable in a radial direction, thus compensating for imbalanced centrifugal force applied to the buckets during a centrifugal separation; and a balance weight moving mean to horizontally move the balance weight in the radial direction of each of the rotating arms.

The buckets may be supported in spaces defined between the rotating arms respectively. Furthermore, each of the rotating arms may include a slot formed through the rotating arm in the radial direction to receive therein the balance weight and guide the horizontal movement of the balance weight. The balance weight may have an internal thread formed through a center of the balance weight. The balance weight moving means may have: a balance weight moving motor, a worm axially coupled to the balance weight moving motor, a worm gear engaging with the worm; and a balance weight moving shaft radially provided in the slot of the rotating arm and having an external thread on an outer surface thereof to engage with the internal thread of the balance weight. The balance weight moving shaft is coaxially coupled at an end thereof to the worm gear.

The automatic balancing rotor may further include a reference position sensing means provided at a predetermined position in the slot of the rotating arm to sense the balance weight placed at a reference position.

MODE FOR THE INVENTION

Hereinafter, an automatic balancing rotor for centrifuges according to a preferred embodiment of the present invention will be described in detail with reference to the attached drawings.

FIG. **2** is a perspective view of an automatic balancing rotor for centrifuges, according to an embodiment of the present invention. FIG. **3** is an exploded perspective view of the automatic balancing rotor of FIG. **2**. FIG. **4** is a sectional view of the rotor taken along the line 4-4 of FIG. **2**. In the drawings, a three-arm swing rotor is shown as an example. As shown in FIGS. **2** through **4**, the automatic balancing rotor for centrifuges according to the embodiment of the present invention includes three rotor arms **29** which support a plurality of buckets **31** containing samples therein. The automatic balancing rotor further includes a balance weight **15** which is provided in each of the rotor arms **29** to compensate for imbalanced centrifugal force applied to the buckets **31** during a centrifugal separation, and a balance weight moving means to horizontally move each balance weight **15** in the radial direction of each rotating arm **29**.

In the above-mentioned construction, the rotor arms **29** are formed by cutting portions of a circular plate having a predetermined thickness at regular angular intervals, so that the buckets **31** are disposed in the cut portions. In this embodiment, the rotor arms **29** are spaced out at 120°

intervals. A pair of bucket support pins **33** is provided on opposite sidewalls of each rotor arm **29** to rotatably support each bucket **31**. Here, each bucket **31** is supported by the cooperation of two adjacent rotor arms **29**.

In the meantime, a slot **29a** is formed through each rotating arm **29** in the radial direction to receive therein each balance weight **15** and guide the horizontal movement of the balance weight **15**. Preferably, the slot **29a** has an elongated rectangular hole shape. Furthermore, it is preferred that the balance weight **15** have a hexahedral shape to prevent the balance weight **15** from rolling in the slot **29a**. An internal thread (not shown) is formed through the center of each balance weight **15**.

Each balance weight moving means has a balance weight moving motor **5** which is provided on a central portion of the automatic balancing rotor such that an output shaft of the balance weight moving motor **5** is vertically disposed. The balance weight moving means further has a worm **7** which is axially coupled to an end of the output shaft of the balance weight moving motor **5**, and a balance weight moving shaft **17** which is longitudinally provided in the slot **29a** of the rotor arm **29**. The balance weight moving shaft **17** has an external thread on an outer surface thereof that engages with the internal thread of the balance weight **15**. The balance weight moving means further has a worm gear **19** which is axially coupled to an end of the balance weight moving shaft **17** and engages with the worm **7**, and a thrust bearing **21** and a radial bearing **23** which are coaxially coupled to opposite ends of the balance weight moving shaft **17**.

To sense a reference position for each balance weight **15** which horizontally moves in the slot **29a**, a reference position sensor **13**, preferably a limit switch, is required. Such a reference position sensor **13** is provided at a predetermined position in each slot **29a** Preferably, the reference position sensor **13** is mounted to a support bracket **11** which extends a predetermined length downwards from a slot cover **9**.

In the drawings, the reference numerals **3** and **1** respectively denote a support frame to support therein the balance weight moving motors **5**, and a motor cap to cover the support frame **3**. The reference numeral **9** denotes a slot cover to cover an open upper end of each slot **29a**. The reference numerals **25** and **27** denote bearing supports to support each thrust bearing **21** and each radial bearing **23** in each slot **29a**, respectively.

FIG. **5** is an electrical block diagram of the operation of a centrifuge having the automatic balancing rotor of the present invention. As shown in FIG. **5**, an electrical construction of the centrifuge having the automatic balancing rotor of the present invention includes a key input unit **110** to select and input various functions provided by the centrifuge having the automatic balancing rotor, and a balance sensing unit **120** which has a weight measuring apparatus (not shown) provided in the centrifuge and senses the weight of the samples contained in the buckets **31**, which are supported by the rotor arms **29**. The electrical construction of the centrifuge further includes a display unit **130** which displays information about the operation of the centrifuge on a display panel, and a control unit **100** which controls the entire operation of the centrifuge. The electrical construction of the centrifuge further includes a balance weight moving unit **150** which moves the balance weight **17** by driving the balance weight moving motor **5** along the balance weight moving shaft **17** from an initial position that is sensed by the reference position sensor **13**. The electrical construction of the centrifuge further includes a signal connection unit **140** which connects a wiring connection board (not shown) to a

wiring layer (not shown) by driving a wiring layer connection motor **170**, thus forming an electrical system capable of transmitting a control command to the balance weight moving unit **150** according to a sensing signal from the balance sensing unit **120**. The electrical construction of the centrifuge further includes a centrifugal separation drive unit **160** which rotates the three-arm swing rotor supporting the buckets **31** therein by driving a rotor drive motor **180**.

In the above-mentioned construction, the balance weight moving motor **5** may be embodied by a stepping motor which is able to precisely control its rotation angle. Alternatively, the balance weight moving motor **5** may be embodied by a servomotor. The control unit **100** includes a balance weight moving distance calculating equation (see equation 1 which will be disclosed herein later) using the difference in weight of the samples, thus calculating the distance to move the balance weight **15** along the balance weight moving shaft **17** using the rotation of the balance weight moving motor **5**.

Hereinafter, the operation sequence and principle of the centrifuge having the automatic balancing rotor of the present invention will be explained in detail.

First, a user puts adaptors (not shown) containing samples in three buckets **31** supported by the bucket support pins **33** of the rotor arms **29**. Thereafter, the user inputs a control command suitable to a centrifugal separating condition for each sample using the key input unit **110**. Then, the control unit **100** transmits the control command to the balance sensing unit **120**. In the balance sensing unit **120**, the weight measuring apparatus having a weight measuring sensor (not shown) measures the weight of the samples contained in the buckets **31** after spatially isolating the buckets **31** from the bucket support pins **33** by raising the buckets **31** upwards. Thereafter, the control unit **100** receives a signal about the weight of the samples measured by the balance sensing unit **120**, and calculates a moving distance of each balance weight **15** to compensate for imbalance of the weight of the samples. Next, the control unit **100** transmits a control command to the signal connection unit **140**, thus driving the wiring layer connection motor **170**, so that the wiring connection board (not shown) is connected to the wiring layer (not shown).

Continuously, to control the rotation angle of each balance weight moving motor **5** corresponding to the calculated moving distance of each balance weight **15** through the connected signal connection unit **140**, the control unit **100** first determines whether each balance weight **15** is placed at the initial reference position or not through a signal received from each reference position sensor **13** through the signal connection unit **140**. Here, if a signal from a reference position sensor **13** indicates that the associated balance weight **15** is placed at an initial reference position, the control unit **100** transmits a control command to the balance weight moving unit **150** through the connected signal connection unit **140** to control the rotation angle of the associated balance weight moving motor **5**. As a result of this, the balance weight **15** is advanced by the calculated distance along the balance weight moving shaft **17**.

On the other hand, if a signal from a reference position sensor **13** indicates that the associated balance weight **15** is not placed at an initial reference position, that is, it is already advanced by a predetermined distance on the associated balance weight moving shaft **17**, the control unit **100** transmits a control command to the balance weight moving unit **150** through the connected signal connection unit **140** to control the rotation angle of the associated balance weight moving motor **5** in a desired direction. Then, the balance

weight **15** is retracted along the balance weight moving shaft **17** to the initial reference position. Simultaneously, the control unit **100** continuously reads a signal from the reference position sensor **13** and determines whether the balance weight **15** reaches the initial reference position or not. When the signal from the reference position sensor **13** indicates that the balance weight **15** reaches the initial reference position, the control unit **100** immediately stops the control signal, which has been transmitted to the balance weight moving motor **5**, and reversely rotates the balance weight moving motor **5**, thus advancing the balance weight **15** by the calculated distance along the balance weight moving shaft **17**.

As such, when the balance weights **15** are moved by the calculated distances along the balance weight moving shafts **17**, the balance weights **15** can compensate for imbalance among the buckets **31** containing the samples therein. As a result, even during the rotation of the automatic balancing rotor, it is possible to maintain the balance of centrifugal force among the samples and balance weights **15**. After balancing the rotor, the control unit **100** transmits a control command to the signal connection unit **140** to drive the wiring layer connection motor **170**, thus separating the wiring connection board from the wiring layer. In this state, the control unit **100** transmits a control command to the centrifugal separation drive unit **160** to drive the rotor drive motor **180**. Then, the centrifuge executes a centrifugal separation process in a balanced state. In the meantime, the display unit **130** displays various kinds of information about both a current setting and operational conditions on the display panel during the centrifugal separation.

Of the description of the above-mentioned operational sequence and principle of the centrifuge having the automatic balancing rotor of the present invention, in the control unit **100**, the moving distance of each balance weight **15** is calculated using the weight difference among the buckets **31** containing the samples which is measured by the weight measuring apparatus, so as to compensate for imbalance of the centrifugal force among the buckets **31** occurring due to the weight difference. This calculation of the balance weight moving distance is executed through a process which will be described step by step. First, the centrifugal force of each bucket **31**, when rotated, is obtained from the weight of the bucket **31**, the distance between the bucket **31** and the rotating shaft of the rotor, and the set rotating speed. A vector value of a total centrifugal force of the buckets **31** is obtained by summing vectors of the centrifugal forces of the buckets **31**. Next a centrifugal force of each balance weight **15** can be determined from the weight of the balance weight **15**, a distance between the balance weight **15** and the rotating shaft of the rotor to be induced, and the set rotating speed

A vector value of a total centrifugal force of the balance weights **15** can be calculated by summing vectors of the centrifugal forces of the balance weights **15**. To balance the centrifuge during the centrifugal separation, a dynamic balance must be maintained between the total centrifugal force vector of the buckets **31** which acts as an imbalancing factor due to the samples contained in the buckets **31**, and the total centrifugal force vector of the balance weights **15** which compensates for or offsets the total centrifugal force vector of the buckets **31**. A distance to move each balance weight **15** along each balance weight moving shaft **17** is obtained using a relational expression for the dynamic balance between the total centrifugal force of the buckets **31** and the total centrifugal force of the balance weights **15**. The

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relational expression for the dynamic balance between the total centrifugal force of the buckets **31** and balance weights **15** is as follows.

$$\sum_{i=1}^{3} m_{b,i}\overline{r_{b,i}}\Omega^2 = -\sum_{i=1}^{3} m_{cw}\overline{r_{cw,i}}\Omega^2 \qquad \text{[Equation 1]}$$

In the above equation 1, the factors $m_{b,i}$ and m_{cw} denote the weight of each bucket **31** and the weight of each balance weight **15**, respectively. The factors $\overline{r_{b,i}}$ and $\overline{r_{cw,i}}$ denote position vectors from the rotating shaft of the rotor toward centers of mass of the bucket **31** and the balance weight **15**, respectively. The factor Ω denotes a rotating speed of the automatic balancing rotor. The equation 1 is for a three-arm rotor. The equation 1 shows that the left side, that is, the sum of centrifugal force vectors of three buckets **31** containing the samples, must be the same as that of the right side, that is, the sum of centrifugal force vectors of three balance weights **1**, so that the total centrifugal force among them must theoretically become zero. From the equation 1, the distance $\overline{r_{cw,i}}$ that each balance weight **15** is moved can be obtained

In the meantime, in the signal connection unit **140**, the wiring layer (not shown), which is connected to an electrical circuit of both the balance weight moving motor **5** and the reference position sensors **13**, is disposed around an output shaft of the rotor drive motor **180**. Accordingly, in a state in which the output shaft of the rotor drive motor **180** is rotated at an appropriate angle, the wiring layer is removably connected to the wiring connection board (not shown) without the entanglement of electrical wires near the rotor arms **29**.

In the balance weight moving unit **150**, an output shaft of each balance weight moving motor **5** is axially coupled to each worm **7** to move the associated balance weight **15** along the associated balance weight moving shaft **17**. In addition, the worm **7** engages with the associated worm gear **19** at an appropriate gear ratio. In such engagement of the worm **7** and worm gear **19**, the worm gear **19** can be driven by the rotation of the worm **7**, but the worm **7** cannot be reversely rotated by the rotation of the worm gear **19**. Therefore, even when the rotor arms **29** rotate at high speed, the balance weights **15** are prevented from undesirably moving along the balance weight moving shafts **17** outwards due to the centrifugal force.

The automatic balancing rotor for centrifuges according to the present invention is not limited to the above-mentioned embodiment, and various modifications are possible, without departing from the scope and spirit of the invention.

For example, a two-arm swing rotor, a four-arm swing rotor or a swing rotor having five arms or more may be used in a centrifuge, in place of the three-arm swing rotor shown in the above-mentioned embodiment. In the case of the two-arm swing rotor, rotor arms are spaced out at 180° intervals. In the case of the four-arm swing rotor, rotor arms are spaced out at 90° intervals. In such a multi-arm swing rotor, balance weight moving units having the same structure must be provided in slots of rotor arms. Furthermore, an engagement of bevel gears or other gears may be used as a balance weight moving unit to control the movement of the balance weights **15** in place of the engagement of the worm **7** and the worm gear **19**. Moreover, a multiple bearing may be used in the balance weight moving unit, in place of the thrust bearing **21** and the radial bearing **23** to support the

balance weight moving shaft **17**, to help smoothly rotate the balance weight moving shaft **17**, and to sustain the centrifugal force of the balance weights. Alternatively, it may be embodied by combined application of the thrust bearing **21** and the radial bearing **23**.

The invention claimed is:

1. An automatic balancing rotor for a centrifuge, comprising:

a plurality of rotating arms having the same radial length and being arranged around a centrifugal rotating shaft, and being spaced out at regular angular intervals, with a plurality of buckets containing samples therein supported by the rotating arms;

a balance weight provided in each of the rotating arms to be movable in a radial direction, thus compensating for imbalanced centrifugal force applied to the buckets during a centrifugal separation, the balance weight including an aperture through a center thereof; and

a balance weight mover to horizontally move the balance weight in the radial direction of each of the rotating arms; the balance weight mover comprising:

a balance weight moving shaft radially provided in the rotating arm and having an outer surface thereof and extending through the aperture of the balance weight, the balance weight being mounted on and movable radia balance weight moving shaft.

2. The automatic balancing rotor for the centrifuge according to claim **1**, wherein the buckets are supported in spaces defined between the rotating arms, respectively.

3. The automatic balancing rotor for the centrifuge according to claim **1**, wherein:

each of the rotating arms comprises a slot formed through the rotating arm in the radial direction to receive therein the balance weight and guide the horizontal movement of the balance weight,

the balance weight has an internal thread formed through the center of the balance weight, and

the balance weight mover comprises:

a balance weight moving motor; a worm axially coupled to the balance weight moving motor; a worm gear engaging with the worm; the balance weight moving shaft being radially provided in the slot of the rotating arm and having an external thread on the outer surface thereof to engage with the internal thread of the balance weight, the balance weight moving shaft coaxially coupled at an end thereof to the worm gear.

4. The automatic balancing rotor for the centrifuge according to claim **1**, further comprising:

a slot formed through each of the rotating arms in the radial direction to receive therein the balance weight and guide the horizontal movement of the balance weight; and

a reference position sensor provided at a predetermined position in the slot of the rotating arm to sense the balance weight placed at a reference position.

5. An automatic balancing rotor for a centrifuge, comprising:

a plurality of rotating arms having the same radial length and being arranged around a centrifugal rotating shaft, and being spaced out at regular angular intervals, with a plurality of buckets containing samples therein supported by the rotating arms;

a balance weight provided in each of the rotating arms to be movable in a radial direction, thus compensating for imbalanced centrifugal force applied to the buckets during a centrifugal separation; and

a balance weight mover to horizontally move the balance weight in the radial direction of each of the rotating arms; and

wherein each of the rotating arms comprises a slot formed through the rotating arm in the radial direction to receive therein the balance weight and guide the horizontal movement of the balance weight,

the balance weight has an internal thread formed through a center of the balance weight, and

the balance weight mover comprises:

a balance weight moving motor; a worm axially coupled to the balance weight moving motor; a worm gear engaging with the worm; and a balance weight moving shaft radially provided in the slot of the rotating arm and having an external thread on an outer surface thereof to engage with the internal thread of the balance weight, the balance weight moving shaft coaxially coupled at an end thereof to the worm gear.

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